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Development of Sea Ice Data Sets from Passive Microwave Satellite Data: Preliminary Lessons

R. L. Weaver, V. J. Troisi, and C. S. Hanson
National Snow and Ice Data Center, CIRES, University of Colorado, Boulder, Colorado, U.S.A.

ABSTRACT

On 19 June 1987 the Defense Meteorological Satellite Program launched the Special Sensor Microwave Imager (SSM/I), a passive microwave radiometer that provides near real-time data for operational use. A computer-based data management system installed at the National Snow and Ice Data Center (NSIDC) extracts polar SSM/I data and produces products suitable for immediate scientific use by the research community. This data processing and management system has been jointly developed by the NASA Ocean Data System (NODS) and NSIDC for NASA Polar Oceans Program.

The premise behind this project is that data archiving, quality control, gridding, and distribution are cost-effective when managed at a central data management facility, and that such an effort provides data of interest, and in forms useful, to the polar remote sensing community and to scientists in cognate disciplines such as atmospheric and ocean sciences.

The system design has changed from the initial 1984 online service concept to the 1990 model, distributing data on CD-ROM and relying on the expertise of individual investigators, and the computing resources of their home institutions, for data analysis. The evolution of the data processing and delivery system, the forces that have driven the changes, and a preliminary assessment of user response are presented in this paper.

INTRODUCTION

The polar regions play a key role in the global environment, serving as primary sinks for energy transported from lower latitudes by the atmosphere and the oceans. They may also serve as sinks for anthropogenic aerosols and trace gases. The variable sea ice cover of the polar oceans greatly influences the world ocean circulation and may contribute to climate change. As well, the polar regions have been shown by modern and paleoenvironmental evidence, and by modeling assessments, to be especially sensitive to climate change.

Over the past two decades, remote sensing by satellite sensors employing all portions of the electromagnetic spectrum has played an increasingly important role in monitoring the polar environment. The utility of visible and infrared sensors on satellite systems, such as the NOAA AVHRR, DMSP OLS, Landsat, and SPOT, is limited for monitoring surface conditions due to persistent cloud cover over the polar oceans and low solar illumination during much of the year. The advantage of using microwave radiometers for mapping sea ice is that microwave emissions from the surface can be monitored year-round with minimal interference from atmospheric moisture. Although the global-scale data exhibit considerable noise due to the nature of the sensors, the remote sensing technique provides a good indicator of sea ice variations over interannual time periods.

Data from various microwave sensors have been collected more or less continuously since 1973 (Figure 1), forming the basis for longer-term monitoring of sea ice [c.f. Gloersen and Campbell, 1988]. The sensor now flying on the DMSP F-8 Satellite is the Special Sensor Microwave Imager (SSM/I), the first passive microwave sensor to pro-

SENSOR HISTORY

HISTORY OF PASSIVE MICROWAVE SENSORS

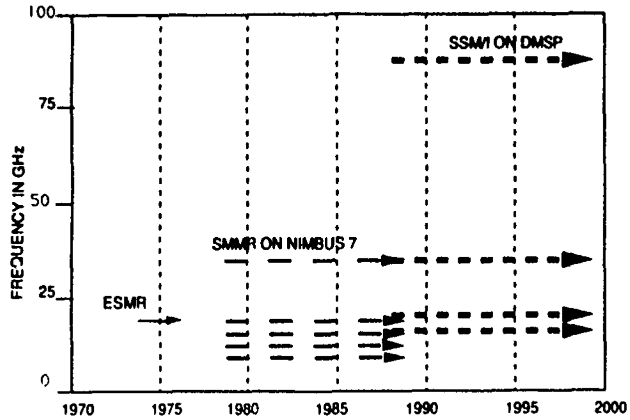

Figure 1. History of passive microwave sensors. Dashed lines of varying thickness indicate time coverage at each frequency in GHz.

1984 MODEL

ALL FUNCTIONS SITUATED ON VAX COMPUTERS AT NSIDC

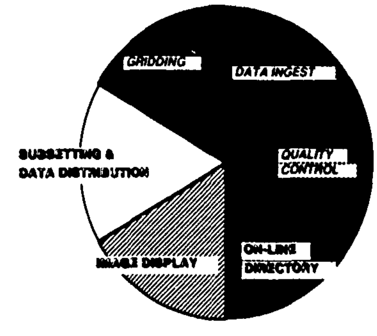

Figure 2. Cryospheric Data Management System, 1984 conceptual model: Central facility.

vide operational data and geophysical products. SSM/I instruments are planned to fly on DMSP platforms for at least the next ten years. The SSM/I provides seven channels of data: dual-polarized radiances at 19.3, 37 and 85.5 GHz and single-polarized radiance at 22.2 GHz. The highest spatial resolution (12.5 km) is provided by the 85 GHz channels.

HISTORY OF THE PROJECT

The NASA-funded effort to archive and distribute SSM/I sea ice products started in 1982. In order to ensure effective use of the SSM/I data for polar cryospheric research, NASA Polar Oceans Program established a Science Working Group (SWG) chaired by Dr. N. Untersteiner. The SWG was tasked to decide which sea ice research problems could most appropriately be addressed using SSM/I data and to define the associated data requirements [NASA-SAWG, 1984].

The general objectives laid out by the SWG included the following:

(1) To provide researchers with gridded brightness temperatures and geophysical data products for the polar oceans;

(2) To make such data conveniently available to a large number of users; and

(3) To facilitate research on (a) sea ice growth, motion and decay, (b) ocean circulation, and (c) climate change.

Rather than design a totally new system for processing SSM/I data, it was decided to adapt the existing Pilot Ocean Data System (now NASA Ocean Data System or NODS). A cooperative project was undertaken by the JPL-NODS and NSIDC staffs to adapt the NODS (PODS) system to the SSM/I data stream, with JPL programming staff to modify the software for SSM/I ingest, product generation and distribution, then "port" it to NSIDC computers, where it would be placed in operation. NODS would be the developer and NSIDC the operator of the SSM/I processing system.

THE 1984 MODEL

When NODS began working on the SSM/I processing system, the only existent model was the centralized data management facility. The following set of assumptions formed the basis for this model:

(1) The system was expected to serve the novice as well as the experienced user;

(2) Minicomputers (VAX class) were the only cost-effective means of data processing for the anticipated volume of data. Scientific workstations were not yet viable; and

(3) Magnetic tape was the internationally accepted medium for transfer of large volumes of data.

Data ingest, quality control, grid production, browse, catalog, data extraction and online display were all part of a closely coupled hardware/software system residing in a single CPU (Figure 2). The model postulated that users would dial up the data system, browse the gridded products, select a subset, and download over the communications circuit. Alternatively, users could request the products be sent by mail on nine-track magnetic tapes.

During 1985–1986, multiple DEC VAX 780s were employed at JPL in a cluster environment, permitting data ingest to be split apart from the various data service functions. This hardware configuration was copied at NSIDC using MicroVAX systems. Also during this time, JPL and others began experimenting with CD-ROM technology as a means of distributing data. These two changes, the availability of small, powerful workstation-type CPUs and the cost-effectiveness of CD-ROM as a distribution medium, led to a more efficient data management operation.

THE 1990 MODEL

The current model (Figure 3) retains portions of the original concept in its central network of CPUs employed for data ingest, quality control, and grid production. Data are distributed on CD-ROMs, moving the subsetting, extraction,

1990 MODEL

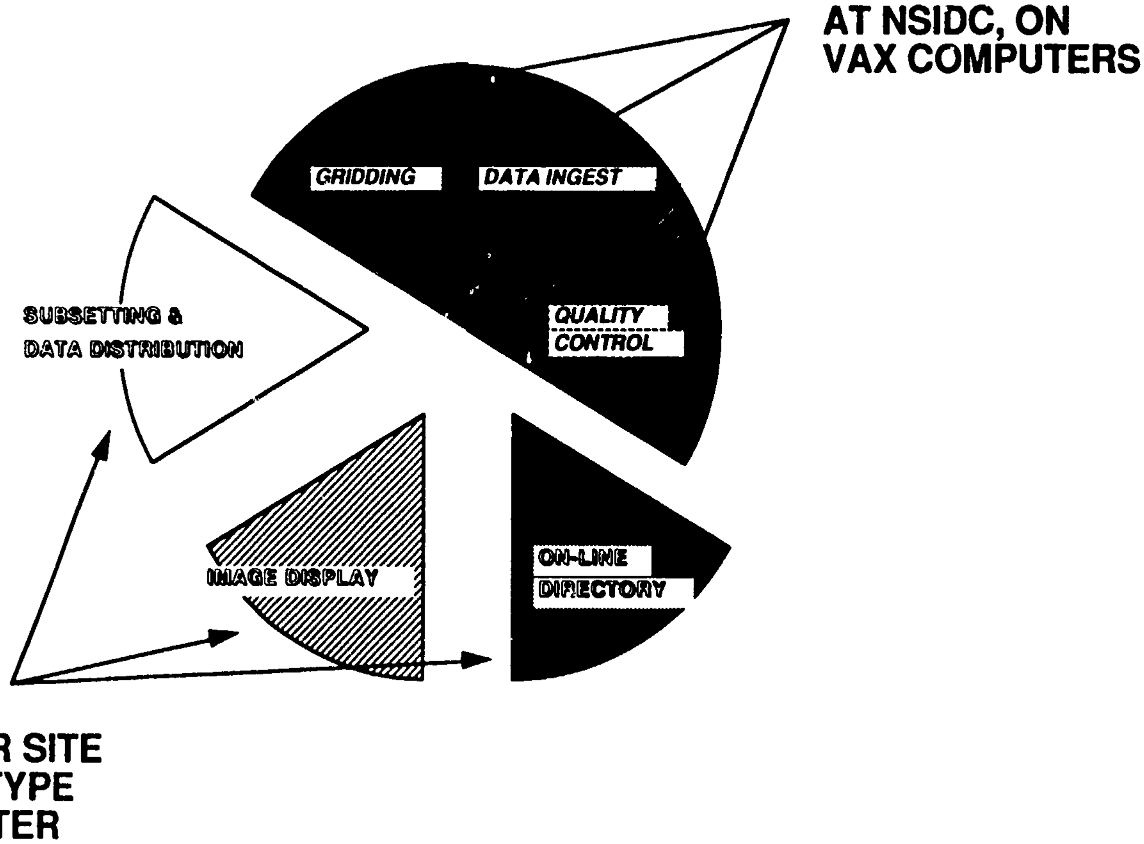

Figure 3. Cryospheric Data Management System, 1990 conceptual model: Distributed system.

and browse (image display) functions to each user's site via software that operates on a PC/AT-class personal computer. The software is provided to users on floppy disks, facilitating distribution of updates and enhancements.

These changes came about in April 1988 at a meeting of the Satellite Ocean Data Systems Science Working Group NODS Advisory Panel. It was decided that the polar oceanographic user community could no longer be considered "novice" computer users, since most had access to PCs and some had acquired scientific workstations. The Panel agreed that AT-class PCs were powerful enough to extract and display the gridded SSM/I products, and in some cases adequate for scientific analysis of the image data. There was also strong support for the concept of distributing the gridded products on CD-ROMs, so that each scientist could have a complete archive on his or her own desk. Thus the concept of a centralized data distribution system for SSM/I data gave way to that of a more limited central facility focusing on data ingest, quality control and grid production with general distribution on CD-ROM. This is the current model at NSIDC.

CURRENT PRODUCTS

The NASA Science Working Group for SSM/I [NASA-SAWG, 1984] recommended four distinct products for the SSM/I archive: global swath-oriented brightness temperatures for all frequencies and polarizations; gridded daily average brightness temperatures for polar regions; gridded total ice concentration, averaged over a 3 day period (i.e., 1 grid/3 days) and multi-year ice fraction for polar regions; and daily ice boundaries. The ice concentrations were to be calculated using the NASA Team Algorithm, which is an implementation of the Nimbus Team Algorithm [Cavalieri et al., 1984; Gloersen and Cavalieri, 1986] with appropriate changes to the brightness temperature tie points.

The Swath-Oriented Brightness Temperature Archive is the basic collection of System Data Records (SDR) from which all data products are generated. These ingest swath antenna temperatures are converted to brightness temperatures through application of an antenna pattern correction algorithm. Time regressions and other irregularities in the lower five channels due to data transmission are removed from the data stream, with the resultant data placed in the NSIDC Rapid Access Archive (RAA). These data are physically stored on 12-inch optical disks.

After launch a significant (up to 75 km) geolocation error was reported by several users. No attempt to correct the geolocation error has been made in the RAA, as only limited access to the RAA is possible. The NSIDC RAA is designed to produce gridded products, not to extract orbital data for

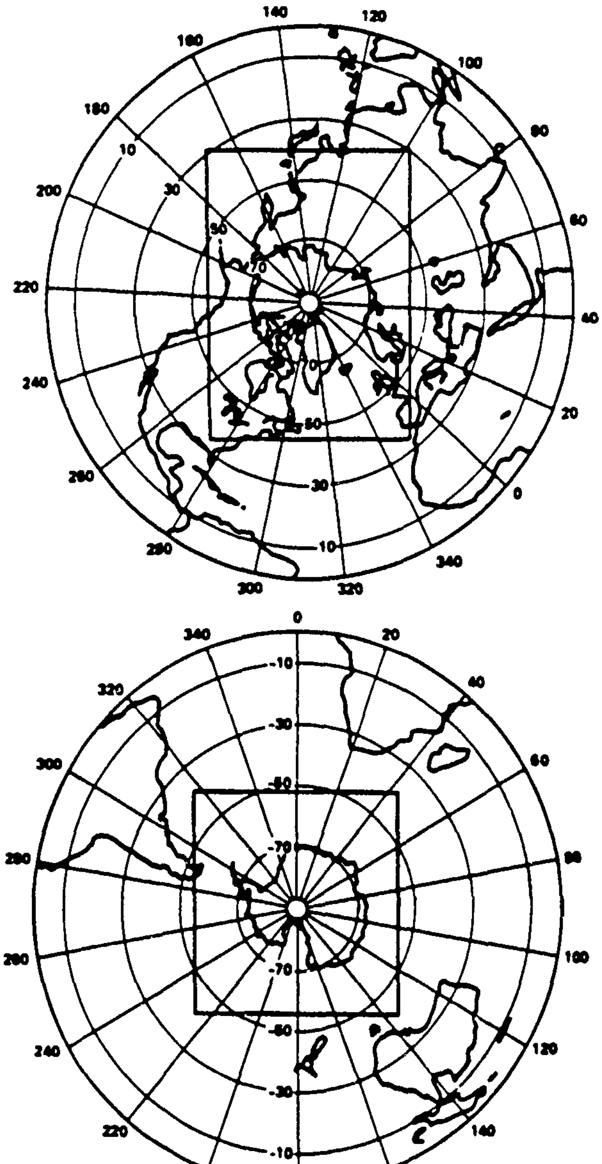

Figure 4. SSM/I North Polar (top) and South Polar geographic grids, polar stereographic projection. Rectangular boxes indicate coverage of the SSM/I gridded sea ice products.

distribution. Most requests for orbital or swath data are directed to NOAA-NESDIS-SDSD (Room 100, Princeton Executive Center, 5624 Allentown Road, Camp Springs, MD, 20233; telephone 301-763-8400), the archive of record for SSM/I orbital data, or to Remote Sensing Systems Inc. (RSS) (Dr. Frank Wentz, Remote Sensing Systems, 1101 College Avenue, Suite 220, Santa Rosa, CA, 95404; telephone 707-545-2904), the current supplier of the SSM/I antenna temperature data.

SSM/I Gridded Products are generated from the RAA onto both north and south polar grids (Figure 4). These are polar stereographic projections, using U.S. Geological Survey formulae [Snyder, 1982] to convert between geodetic and Cartesian coordinates. The ellipsoid is based upon the Hughes ellipsoid, similar to those presented by Snyder. The SSM/I grids have the standard latitude at 70°, with the origin of the grids at each pole.

There are six SSM/I grids, three for the Northern Hemisphere (N3A, N3B and N3C) and three for the Southern Hemisphere (S3A, S3B and S3C). The "A" grids contain the 85 GHz brightness temperatures, the "B" grids contain brightness temperatures from all other channels, and the "C" grids contain calculated sea ice concentrations. Although the resolution varies, each grid represents the same geographic area, with multiple parameters interleaved in each grid cell. Details of the grid structure and content may be found in the SSM/I CD-ROM user's guide [National Snow and Ice Data Center, 1990]. Gridded ice extent was dropped from the product suite because ice extent can be extracted readily by the user from the sea ice concentration grids.

For 1987–1988 data, NSIDC applied a geolocation correction based on the roll, yaw and pitch angles of the DMSP spacecraft. The algorithm that corrects for both along-track and cross-track errors was developed at the University of Massachusetts [NSIDC, 1989]. Beginning with the 1989 data, Remote Sensing Systems, Inc., began computing its own latitudes and longitudes in order to correct these location errors. Even so, a 0.5° yaw error appeared in the data. RSS then supplied NSIDC with an algorithm designed to correct this constant yaw angle offset [Wentz, 1989]. This algorithm has replaced the University of Massachusetts correction algorithm in the production of SSM/I brightness temperature grids at NSIDC.

NSIDC has recently completed a location quality assessment [Sandoval and Troisi, in preparation] with these gridded data without finding concrete evidence of significant geolocation error. Final conclusions have not yet been drawn from this study, but if the results of this or other studies warrant, the data could be reprocessed and a new CD-ROM product made available for distribution.

Gridded brightness temperatures for 9 July 1987 to 24 July 1988 have been released on four CD-ROM disks. To date, no sea ice concentrations have been distributed, although software to calculate sea ice concentration using the NASA Team Algorithm has been provided with all CD-ROM sets sent to users. The NASA SSM/I Sea Ice Algorithm Validation Team Final Report [Cavalieri et al., 1991], containing the final approved tie points for the NASA Team Algorithm, will be released soon. NSIDC will produce and distribute a sea ice concentration product based on this algorithm as soon as the report is released. As of 31 March 1991, the NASA Team Algorithm tie points have been approved and provided to NSIDC. Production of the sea ice concentration time series CD-ROM has begun, with projected completion in third quarter 1991.

At an April 1990 SSM/I Sea Ice Algorithm Workshop at Goddard Space Flight Center several alternate algorithms were presented by members of the community. Intercomparisons of these candidate algorithms are being carried out at this time. If any of these alternative algorithms are shown to perform more accurately than the Team Algorithm, NSIDC may also produce a second sea ice concentration CD-ROM set using the alternate algorithm(s).

ASSESSMENT OF USER RESPONSE

As of 6 June 1990, 229 CD-ROM sets have been distributed (Figure 5). A questionnaire was included with each

CD-ROM DISTRIBUTION

- **229 CD-ROM BRIGHTNESS TEMPERATURE DATA SETS (VOL 1-4) DISTRIBUTED AS OF 6 JUNE 1990**
- **USER TYPES ARE :**

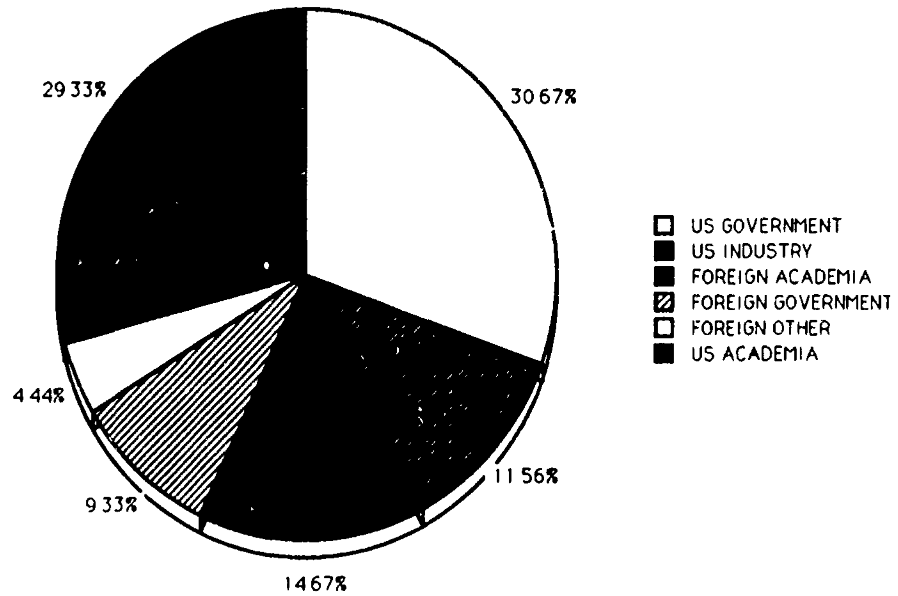

Figure 5. Distribution of SSM/I CD-ROM as of 6 June 1990. U.S. Government and U.S. academic users predominate.

CD-ROM shipment; 29% (67) have been returned to date. Some interesting information is found in the responses:

(1) 93% (62) of users returning the questionnaire would like to receive more SSM/I data on CD-ROM;

(2) 79% (53) of users returning the questionnaire would like to receive the SMMR data (1978–1987), also published on CD-ROM;

(3) Comments added to the questionnaires were uniformly positive with the exception of one non-specific complaint about the software (now being followed up by NSIDC staff) and one very strong demand for Apple Macintosh versions of the extraction and display software.

There is not yet sufficient specific feedback to provide an accurate assessment of user satisfaction. However, the 62 respondents who wish to receive additional SSM/I data on CD-ROM indicate satisfaction with the product at least at the level of willingness to continue using the product. Because the first distributions occurred only five months ago, we believe it may be too early to draw conclusions about either the acceptability of the gridded products or the utility of the distribution format.

CONCLUSIONS

There are several generalizations that can be drawn from the past eight years of effort, regarding data management and the SSM/I data products. It is clear from the relatively rapid technological changes that have taken place that the operative concepts of 1984 do not apply in 1990. We conclude that a responsive data center is one that is able to take advantage of technological advances. NSIDC is fortunate in the case of SSM/I data processing to have had the resources and expertise available, both locally and at JPL, to incorporate changes in technology.

Likewise, the needs and capabilities of the user community to digest digital data have changed markedly as a result of the same technological advances. A data center serving a dynamic user community must adapt to these changing needs, no matter how often they change. It is important to note there is continuing dynamic tension between available resources and meeting these (sometimes strident) demands for modified products.

It is too early to assess completely the adequacy of the gridded passive microwave products or the viability of CD-ROM as a distribution medium. Preliminary indications suggest, however, that both the product and the medium are acceptable and are being used actively for research and algorithm development. NSIDC continues to solicit and monitor user feedback. It is worth noting that verbal comments in support of "getting the data out to the users" by means of the CD-ROMs are numerous and frequent. There is considerable, but not overwhelming, support for adaptation of the CD-ROM product to SUN, Macintosh, and VAX CPUs. Macintosh access and display software is under development at NSIDC in association with Dr. W. Emery (University of Colorado, Colorado Center for Astrodynamics Research). A "beta" version of this software is now being distributed to users who have indicated an interest, for evaluation and comment.

ACKNOWLEDGMENTS

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REFERENCES

Cavalieri, D. J., P. Gloersen, and W. J. Campbell, Determination of sea ice parameters with the NIMBUS-7 SMMR, *J. Geophys. Res.*, *89*, 5355–5369, 1984.

Cavalieri, D. J., J. Crawford, M. Drinkwater, W. Emery, D. T. Eppler, L. D. Farmer, M. Goodberlet, R. Jentz, A. Milman, C. S. Morris, R. Onstott, A. J. Schweiger, R. Schuchman, K. Steffen, C. T. Swift, C. Wacherman, and R. L. Weaver, *NASA DMSP SSM/I Sea Ice Validation Program, Final Report*, 1991, In press.

Gloersen, P., and W. J. Campbell, Variations in the Arctic, Antarctic and global sea ice covers during 1978–1987 as observed with the Nimbus-7 Scanning Multichannel Microwave Radiometer, *J. Geophys. Res.*, *93*, 10666–10674, 1988.

Gloersen, P., and D. J. Cavalieri, Reduction of weather effects in the calculation of sea ice concentration from microwave radiances. *J. Geophys. Res.*, *91*, 3913–3919, 1986.

NASA-SAWG (National Aeronautics and Space Administration, Science Working Group for Special Sensor Microwave Imager), *Passive Microwave Remote Sensing for Sea Ice Research*, 55 pp., NASA, Code EE, Washington, DC, 1984.

NSIDC (National Snow and Ice Data Center), Geolocation correction to be applied to SSM/I gridding procedure, *CDMS Notes*, *3*, 4, 1989.

NSDIC, *DMSP SSM/I Brightness Temperature Grids for the Polar Regions on CD-ROM, User's Guide*, looseleaf, National Snow and Ice Data Center, Boulder, CO, 1990.

Sandoval, N. A., and V. J. Troisi, SSM/I *Brightness Temperature Grids: Quality Control Assessment*, NSIDC (In preparation).

Snyder, J. P., *Map Projections Used by the U.S. Geological Survey*, U.S. Geological Survey Bulletin 1532, 1982.

Wentz, F., *Update for 1989 Compact TA Tapes*, 1989 (also in *DMSP SSM/I Brightness Temperature Grids for the Polar Regions on CD-ROM, User's Guide*, Appendix 1, National Snow and Ice Data Center, Boulder, CO, 1990).